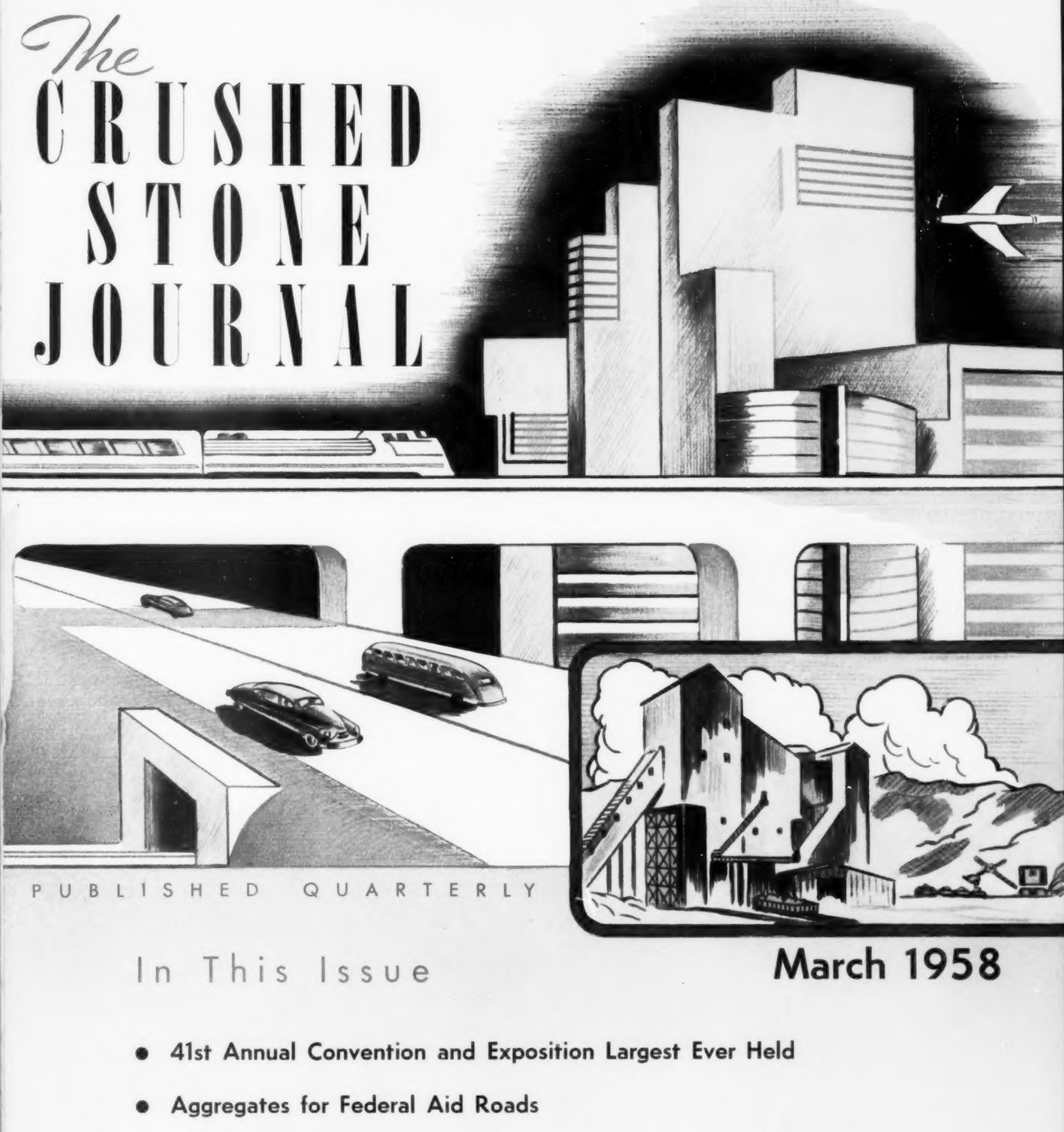
The CRUSHED STONE JOURNAL



PUBLISHED QUARTERLY

In This Issue

March 1958

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- Aggregates for Federal Aid Roads
- Road Blocks in the Highway Program
- This Problem of Skid Resistance

OFFICIAL PUBLICATION · NATIONAL CRUSHED STONE ASSOCIATION

PLAN TO ATTEND

NCSA *42nd*
ANNUAL CONVENTION

AMERICANA
HOTEL

WEEK OF *JANUARY 25, 1959*

MIAMI BEACH, FLORIDA

The Crushed Stone Journal

Official Publication of the NATIONAL CRUSHED STONE ASSOCIATION

J. R. BOYD, Editor

NATIONAL CRUSHED STONE ASSOCIATION

1415 Elliot Place, N. W.
Washington 7, D. C.

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O. E. BENSON

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General Crushed Stone Co.
Easton, Pa.

●

Elected President
NATIONAL CRUSHED STONE ASSOCIATION
by its Board of Directors
Chicago, Illinois

February 16, 1958

L. A. EIBEN

President
Northern Blower Company
Cleveland, Ohio

●

Elected Chairman
MANUFACTURERS DIVISION
by its Board of Directors
Chicago, Illinois

February 16, 1958

THE CRUSHED STONE JOURNAL

W A S H I N G T O N , D . C .

Vol. XXXIII No. 1 PUBLISHED QUARTERLY MARCH 1958

41st Annual Convention and Exposition Largest Ever Held

O. E. Benson Elected President
L. A. Eiben Heads Manufacturers Division

JUST short of 2,000 people met in Chicago, Illinois, for the 41st Annual Convention and Manufacturers Division Exposition of the National Crushed Stone Association. It is interesting to compare the magnitude of this 41st record-breaking NCSA Annual Convention with the 1st held in Chicago 40 years ago, when only 55 crushed stone producers met for one day to form the National Crushed Stone Association and to discuss industry problems.

Record crowds filled the various sessions and packed the 20,000 square feet of the Manufacturers Division Exposition which occupied the entire lower level exposition area of the Conrad Hilton Hotel.

The time and effort spent by the Convention Arrangements Committee, under the capable Chairmanship of O. E. Benson, reaped big dividends as evidenced from the many flattering comments made by the members and guests.

NCSA members and nationally known guest speakers presented unusually fine papers of real value and lasting importance. The resounding applause following the talks left no doubt as to the interest of the audience.

From early morning until late evening members and guests took advantage of this unequalled opportunity to discuss individual problems and those of the industry with other producers and the nationally known authorities on the Convention program.

Several of the Convention papers are included in this issue of the Crushed Stone Journal, others either will be mimeographed or published in pamphlet form and made available to the membership in the very near future.

Wednesday Night's NCSA Dinner Dance, February 19, 1958, Grand Ballroom, Conrad Hilton Hotel, Chicago, Illinois

O. E. BENSON
General Crushed Stone Co.
Easton, Pa.
President
National Crushed Stone Association

W. C. ROWE
Rowe Contracting Co.
Malden, Mass.
Vice President
National Crushed Stone Association

N. E. KELB
Cumberland Quarries, Inc.
Indianapolis, Ind.
Immediate Past President

H. C. KRAUSE
Columbia Quarry Co.
St. Louis, Mo.
Elected Past President

EXECUTIVE COMMITTEE

of the

NATIONAL CRUSHED STONE ASSOCIATION

for 1958

CLARENCE CAMP, II
Camp Concrete Rock Co.
Ocala, Fla.

CHARLES COBURN
Waukesha Lime & Stone Co., Inc.
Waukesha, Wis.

L. A. EIBEN
Northern Blower Co.
Cleveland, Ohio
Chairman
Manufacturers Division

G. D. LOTT, JR.
Palmetto Quarries Co.
Columbia, S. C.

R. S. REIGELUTH
New Haven Trap Rock Co.
New Haven, Conn.

NELSON SEVERINGHAUS
Consolidated Quarries Corp.
Decatur, Ga.

D. L. WILLIAMS
Virginian Limestone Corp.
Ripplemead, Va.

O. E. Benson Elected President

The Board of Directors of NCSA, elected by mail ballot prior to the Annual Convention, held its organizing meeting Sunday afternoon, February 16, 1958, at which time in accordance with the By-Laws the Board elected the officers and Executive Committee for the ensuing year.

O. E. Benson, President of the General Crushed Stone Company, of Easton, Pennsylvania, was unanimously elected President of the National Crushed Stone Association. President-Elect Benson expressed his deep appreciation to the Board of Directors for the confidence placed in him, and pledged his untiring efforts to further the aims and purposes of the Association.

Other officers elected were as follows:

Vice President—W. C. Rowe,
Rowe Contracting Co.
Malden, Mass.

Treasurer —J. R. Callanan,
Callanan Road Improvement Co.
South Bethlehem, N. Y.

Secretary —J. R. Boyd,
National Crushed Stone
Association, Washington, D. C.

Election of Executive Committee

From the Past Presidents eligible to serve on the Executive Committee, three names were placed in nomination and, by secret ballot, H. C. Krause was elected to serve on the Executive Committee for the year 1958.

From the elected members of the Board of Directors, eligible to serve on the Executive Committee, 8 names were placed in nomination with 6 to be elected. Following a secret ballot, Clarence Camp, II, Charles Coburn, G. D. Lott, Jr., R. S. Reigeluth, Nelson Severinghaus, and D. L. Williams were declared elected to serve on the Executive Committee for the year 1958.

The entire Executive Committee, including the elected and ex officio members, is as follows:

Executive Committee

O. E. Benson, General Crushed Stone Co., Easton, Pa., *Chairman*

Clarence Camp, II, Camp Concrete Rock Co., Ocala, Fla.

Charles Coburn, Waukesha Lime and Stone Co., Waukesha, Wis.

L. A. Eiben, Northern Blower Co., Cleveland, Ohio

N. E. Kelb, Cumberland Quarries, Inc., Indianapolis, Ind.

H. C. Krause, Columbia Quarry Co., St. Louis, Mo.

G. D. Lott, Jr., Palmetto Quarries Co., Columbia, S. C.

R. S. Reigeluth, New Haven Trap Rock Co., New Haven, Conn.

W. C. Rowe, Rowe Contracting Co., Malden, Mass.

Nelson Severinghaus, Consolidated Quarries Corp., Decatur, Ga.

D. L. Williams, Virginian Limestone Corp., Ripplemead, Va.

Organizing Meeting of Newly Elected NCSA Board of Directors

NEWLY ELECTED TO NCSA BOARD


H. H. Haas
Houdaille
Industries, Inc.
Buffalo, N. Y.


D. C. Harper
Southwest
Stone Co.
Dallas, Texas


A. W. Heitman
Inland Lime
and Stone Co.
Div. Inland Steel Co.
Manistique, Mich.


J. S. Kaufman
Marble Cliff
Quarries Co.
Columbus, Ohio


K. K. Kinsey
Concrete Materials
and Construction Co.
Cedar Rapids, Iowa

Other Elections


J. R. Callanan
Callanan Road
Improvement Co.
South Bethlehem,
N. Y.
Elected Treasurer

W. N. Carter, Joliet, Ill., S. P. Moore, Cedar Rapids, Iowa, H. E. Rodes, Nashville, Tenn., O. M. Stull, Buchanan, Va., Stirling Tomkins, West Nyack, N. Y., and Harlod Williams, Boston, Mass., were all unanimously elected as Honorary Members of the Board of Directors.

A. N. Foley of West Roxbury Crushed Stone Co., West Roxbury, Mass., was elected as Regional Vice President for the New England Region to fill the vacancy left when Mr. Rowe was elected Vice President of the Association.

The 9 Regional Vice Presidents and the area each represents appear on page 7.

L. A. Eiben Elected Chairman of Manufacturers Division

Two hundred and forty representatives of the Manufacturers Division met Tuesday, February 18, 1958, for their Annual Meeting, at which time the results of the elections held during the organizing meeting of the Board of Directors were announced. As reported by B. R. Maloney, Chairman of the Nominating Committee, the following were elected to office by the Board of Directors.

Chairman

L. A. Eiben, Northern Blower Co., Cleveland, Ohio

Vice Chairman

R. D. Ketner, General Electric Co., Schenectady, N. Y.

Organizing Meeting of Newly Elected Board of Directors Manufacturers Division NCSA

Regional Vice Presidents for 1958

National Crushed Stone Association

A. N. FOLEY
New England
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont

D. C. HARPER
Southwestern
Arizona, Arkansas, Louisiana, New Mexico, Oklahoma, Texas

R. G. L. HARSTONE
British Commonwealth
Dominion of Canada, United Kingdom, Australia, New Zealand, Union of South Africa

A. W. HEITMAN
Northern
Michigan, Minnesota, Montana, Nebraska, North Dakota, South Dakota, Wisconsin

J. L. HOLDEN
Eastern
Delaware, Maryland, New Jersey, New York, Pennsylvania, District of Columbia

K. K. KINSEY
Midwestern
Illinois, Indiana, Iowa, Kansas, Missouri

A. W. McTHENIA
Central
Kentucky, Ohio, Tennessee, West Virginia

N. SEVERINGHAUS
Southeastern
Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, Virginia

B. G. WOOLPERT
Western
California, Colorado, Idaho, Nevada, Oregon, Utah, Washington, Wyoming, Territory of Hawaii

Elected Members of Executive Committee

I. F. Deister, Deister Machine Co., Fort Wayne, Ind.

W. E. Collins, Jr., Atlas Powder Co., Wilmington, Del.

J. M. Hume, Pettibone Mulliken Corp., Chicago, Ill.

Additional Members of Executive Committee—Ex Officio

Wayne W. King, W. S. Tyler Co., Cleveland, Ohio, Immediate Past Chairman

O. E. Benson, General Crushed Stone Co., Easton, Pa., President of NCSA

On behalf of the Manufacturers Division, Mr. King, retiring Chairman, was presented with an appropriately worded plaque as a small token of appreciation for his outstanding service to the Manufacturers Division and NCSA. The plaque was inscribed as follows:

For Distinguished Service
WAYNE W. KING
Chairman 1956-57
MANUFACTURERS DIVISION
NATIONAL CRUSHED STONE ASSOCIATION

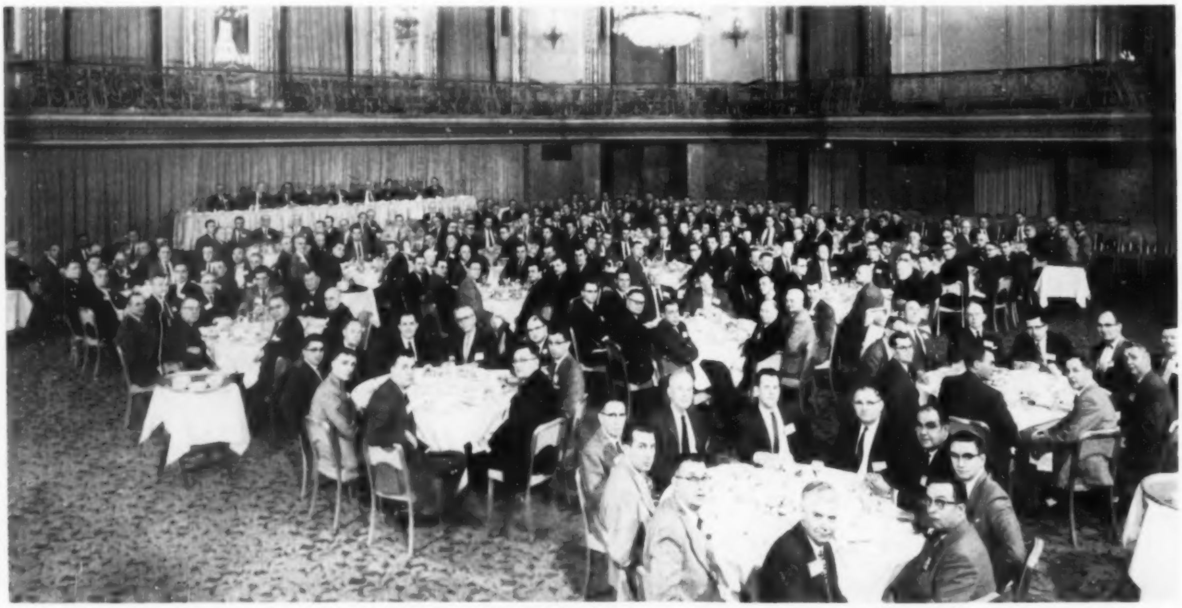
In heartfelt response Mr. King thanked the officers and Boards of Directors of the Division and NCSA for their cooperation and help during his Chairmanship.

L. W. Shugg, Director of Exhibits, Left, and Wayne W. King, Chairman of Manufacturers Division

Division Membership Grows

An all-time high of 126 members or an increase of 10 new members over last year was reported at the Manufacturers Division Annual Meeting.

Another indication of the rapid growth of the Division was noted in connection with the Biennial Exposition where 89 members of the Manufacturers Division exhibited their products and services. The Exposition was the largest, and from the many comments of producers and exhibitors, the most successful ever held in conjunction with an NCSA Convention.



Manufacturers Division Luncheon, February 18, 1958, Grand Ballroom, Conrad Hilton Hotel, Chicago, Illinois

L. A. Eiben
Northern Blower Co.
Cleveland, Ohio
Chairman
Manufacturers Division

R. D. Ketner
General Electric Co.
Schenectady, N. Y.
Vice Chairman
Manufacturers Division

EXECUTIVE COMMITTEE

of the

MANUFACTURERS DIVISION

National Crushed Stone Association

for 1958

O. E. Benson
General Crushed
Stone Co.
Easton, Pa.
President
National Crushed
Stone Association

W. E. Collins, Jr.
Atlas Powder Co.
Wilmington, Del.

I. F. Deister
Deister Machine Co.
Fort Wayne, Ind.

J. M. Hume
Pettibone
Mulliken Corp.
Chicago, Ill.

Wayne W. King
W. S. Tyler Co.
Cleveland, Ohio

Past Chairmen, Manufacturers Division

Reading Clockwise: J. C. McLanahan, '50-'51; I. F. Deister, '52-'53; B. R. Maloney, '54-'55; Cottrell Farrell, '48-'49; Abe Goldberg, '32-'33; J. H. Fulkerson, '41-'43; M. B. Garber, '26; M. A. Nice, '44-'45.

Many Social Activities

A wide variety of social activities designed to break the heavy Convention schedule with occasions to meet and talk to fellow producers and manufacturers also provided pleasant relaxation. Commencing with a Greeting Luncheon Monday and ending with Wednesday night's dinner dance, the social affairs of the 41st Annual Convention will be remembered by all for some time to come. The NCSA Frolic was held Monday night amid gay decorations suggestive of the Circus. People thronged past "fun mirrors" to be greeted by "Punkin" the clown who passed out party hats and escorted members and guests to their tables under the helpful protection of his unique umbrella. Tables were brightly decorated with checkered cloths and miniature carousels, adding color to the already informal atmosphere.

Wednesday night's celebration suitably climaxed the three day convention with a delightfully different and informal Dinner Dance. Music for dancing was provided by one of Chicago's finest orchestras, and its selections appealed to the carefree happy mood of the crowd for the dance floor was never empty. The entertainment was varied and good, causing several unscheduled encores. A light fingered Master of Ceremonies kept the huge audience spellbound with his unusual antics as he removed wrist watches, wallets, and suspenders from unsuspecting volunteers. It would be very difficult indeed to improve on an affair so thoroughly enjoyed—or to plan an evening more conducive to good fellowship.

Ladies Luncheon and Fashion Show

Hostesses for Ladies Entertainment
Mrs. H. H. Clark, Mrs. N. E. Kelb, Mrs. Wayne W. King

Ladies Entertainment

Three gracious and charming Hostesses, Mrs. Harry A. Clark, Mrs. Norman E. Kelb, and Mrs. Wayne W. King, outdid themselves in their efforts to see that the Ladies attending the Convention enjoyed every minute. Up bright and early the trio were on hand to greet the ladies as they gathered for coffee and sweet rolls in the Ladies Headquarters before starting the activities of the day. One of several highlights on the Ladies Program was a Fashion Show and Luncheon in the uniquely decorated Mayfair Room of the Blackstone Hotel. Miss Maggie Daly, local TV personality and Fashion Commentator, acted as Mistress of Ceremonies during the well attended affair featuring the very latest in Spring fashions. In addition to the regular events scheduled on their program the ladies found much to their liking in Chicago ranging from sightseeing to shopping in some of the nation's most famous department stores.

1956 NCSA Safety Contest Winners

Top Row, *left to right:* W. D. Milne for Webster Quarry, President, Kentucky Stone Co., Irvington, Ky.; Luther Fourman, Representative elected by his fellow employees, for Plant No. 1, Callanan Road Improvement Co., South Bethlehem, N. Y.; W. J. Wise for Plant No. 4, Vice President, Southwest Stone Co., Knippa, Texas; John Cox, Supt., Watertown Quarry, General Crushed Stone Co., Watertown, N. Y.; H. P. Jones, Supt., Auburn Quarry, General Crushed Stone Co., Auburn, N. Y.; E. L. Childs, Supt., Pixley Mine, Stewart Sand & Material Co., Independence, Mo.; Henry Patrick, Supt., Plant No. 2, Catskill Mountain Stone Corp., Hudson, N. Y.; Ray Vencill for Tyrone Mine, Gen. Supt., Kentucky Stone Co., Tyrone, Ky.; **Middle Row**, *left to right:* O. C. Dietschler, Supt., Jordanville Quarry, General Crushed Stone Co., Jordanville, N. Y.; G. B. Phillips for Kimballton and Bakerton Mines, Asst. Gen. Supt., Standard Lime & Cement Co., Pearisburg, Va. and Bakerton, W. Va.; R. L. Walker, Supt., Cheektowaga Quarry, Federal Crushed Stone Corp., Cheektowaga, N. Y.; O. E. Benson for Oaks Corners Quarry, President, General Crushed Stone Co., Geneva, N. Y.; Robert Santmier, Eastern Rock Products, Inc., substituting for Jesse Haney, Supt., Prospect Stone Plant No. 6, Prospect, N. Y.; W. L. Stanley, Supt., Bessemer Quarry, Bessemer Limestone & Cement Co., Bessemer, Pa.; Hiram Towne, Supt., Oriskany Falls Stone Plant No. 5 Quarry, Eastern Rock Products, Inc., Oriskany Falls, N. Y.; **Bottom Row**, *left to right:* Gene Andres, Supt., No. 8 Quarry, Columbia Quarry Co., Ullin, Ill.; E. A. Heise, Supt., Krause No. 1 Quarry, Columbia Quarry Co., Columbia, Ill.; Stirling Tomkins, New York Trap Rock Corp., substituting for John Jorgensen, Supt., Tomkins Cove Quarry, Tomkins Cove, N. Y.; H. H. Kirwin, Treasurer, Eastern Rock Products, Inc., Utica, N. Y., *Chairman*, NCSA Accident Prevention Committee; J. O. Sherod for Bell Mine, Cedar Hollow, and Union Furnace Quarries, Mgr., Lime Div., Warner Co., Bellefonte, Pa., DeVault, Pa., and Tyrone, Pa.; A. W. Heisler, Supt., Stafford Quarry, Genesee Stone Products Corp., Stafford, N. Y.; Emil Berry for Avoca Quarry, President, Jefferson County Stone Co., Inc., Avoca, Ky.; A. W. Zimmer, Jr. for Cape Girardeau Mine, Gen. Mgr., Federal Materials Co., Inc., Cape Girardeau, Mo.

Bell Mine of Warner Company Wins Safety Contest For Third Year

The Bell Mine of the Warner Company, Philadelphia, Pennsylvania, received the bronze plaque for the 1956 NCSA Safety Contest for the third consecutive year, and in so doing obtained permanent possession of this coveted award provided by the Explosives Engineer Magazine. In accepting the award on behalf of the employees of Bell Mine, J. E. Sherod, Manager, Lime Division of the Warner Company, expressed his deep appreciation to the U. S. Bureau of Mines, the Explosives Engineer Magazine, and to NCSA, as well as the other companies in the contest who through their keen competition provided the incentive. The Bell Mine has been a participant in the Safety Contest for 28 years and in that time has operated more than 6 million man hours. H. A. Corre, Superintendent of Bell Mine, reported a total of 277,540 man hours worked without a single lost-time accident in 1956, a record that clearly demonstrates what a well-developed and implemented program of accident prevention can achieve.

Reproductions of the bronze plaque in the form of Certificates of Honorable Mention were presented to representatives of the other 31 perfect record plants which had participated in the 1956 Contest. In addition, individual employees of each winning plant were sent Certificates of Award by the National Crushed Stone Association in recognition of their part in building such impressive safety records.

J. E. Sherod, Accepting the Safety Contest Award for Bell Mine of Warner Co., Bellefonte, Pa.

Aggregates for Federal Aid Roads[1]

By HAROLD ALLEN

Chief, Division of Physical Research
U. S. Bureau of Public Roads
Washington, D. C.

SINCE the passage of the Federal Aid Highway Act of 1956 it has become the practice for speakers at public functions to begin with statistical data regarding mileage and finances authorized by that law. I shall follow the usual pattern in an effort to establish a background for my discussion.

Essential Provisions of 1956 Act

The 1956 Act provides for the improvement of two principal systems (1) the 250,000 mile federal aid primary system which includes the 41,000 miles in the interstate network and (2) the federal aid secondary system consisting of 528,000 miles. This 778,000 mile total is eligible for improvement with federal aid funds. The $25 billion provided for the interstate system was to be expended in 10 to 13 years but tax revenues going to the trust fund will not allow the originally authorized rate of construction. Therefore the construction period will be extended over a somewhat longer period. ABC funds of $850 million for the fiscal year 1958 and $875 million for 1959 have been made available. (The "ABC" designation is derived from section 102 of the Act which sets forth authorizations for the primary, secondary, and urban sections under subparagraphs A, B, and C.) The ABC funds must be matched on a 50-50 basis by the states and the interstate funds on a 90 per cent federal and 10 per cent state basis. It seems obvious that the construction of the new projects provided for by these funds and the maintenance of the existing system will require a volume of aggregates which may tax production facilities to the very limit.

Aggregate Demand

It is estimated that for highway construction in 1958 the demand on commercial producers of aggregates will be about 250 million tons. This is expected to increase to about 300 million tons in 1960, and to remain at that figure through 1967. If we assume that two-thirds of the total is coarse aggregate (larger than 1/4 in.) and that 50 per cent of that coarse aggregate is crushed stone, 100 million tons of crushed stone from commercial sources per year will be required to keep the highway program moving along at the expected rate. In addition to the aggregates purchased from commercial sources, contractors produced approximately 300 million tons in 1957 and this will increase to about 400 million tons by 1960 and remain at that level through 1967. The total crushed stone from both sources will be about 233 million tons per year after 1960. We feel that in order to meet these demands it will be necessary to give close attention to the economical use of all aggregate supplies. The known supply in some states is extremely limited and is being depleted rapidly. In some areas, either aggregates of any type are non-existent or the cost from commercial sources is prohibitive due to long hauls. It is important that the best possible use be made of aggregates that are available.

Aggregate Classification

With respect to usage, highway materials may be classified as follows:

1. Aggregates for use in structural concrete, concrete pavement, bituminous surfaces, and base courses.
2. Aggregates for use in subbases under concrete pavements or under base courses for bituminous surfaces, and in shoulders.

Aggregates for class 1 work must be carefully graded and be reasonably free from deleterious materials, such as shale and soft particles. Commercially established plants usually produce aggregates in this class. However, the development of local sources of aggregates will be necessary in areas that are not within an economical haul distance from a commercial source. For example, on a large section of a midwestern toll road, stone from local quarries was used in the base and surfacing at a considerable saving in cost. Blending of aggregates

[1] Presented at the 41st Annual Convention of the National Crushed Stone Association, Conrad Hilton, Chicago, Illinois, February 17-19, 1958

from two or more sources may be necessary to produce a satisfactory material.

Although aggregates in class 2 must have satisfactory quality for the specific use, the grading of materials for subbases may be less critical and a greater percentage of deleterious particles may be tolerated than in class 1 materials. Stone screenings, which are often considered as waste materials, have been frequently used in subbases. Dune sands have given good service as subbases for concrete pavements in one state. The admixture of a small percentage of portland cement with plastic pit-run sand-gravel materials has resulted in a satisfactory subbase material for both concrete and bituminous pavements in another state. Sand-clay or sand-gravel mixtures with a plasticity index as high as 9 may be used in shoulder construction. Soil stabilization with portland cement or lime may be necessary for subbases and shoulders in areas where aggregates are not available.

The highway departments are being urged to give careful consideration to the use of class 2 materials when preparing plans and specifications, and thereby conserve the more expensive and scarce class 1 materials. Many highway departments are now following this practice.

Also highway departments are being urged to develop information regarding local sources of aggregates by the use of all available survey procedures. A state-wide materials survey is considered as research and may be financed on a cooperative basis with federal funds.

Aggregate Quality

Let us consider very briefly some of the quality requirements for class 1 aggregates for use in all federal aid highway construction. In the past the Bureau of Public Roads has insisted that aggregates be of such quality as to insure satisfactory performance of structures and pavements. It is our desire to maintain that policy on future work. As far as we know the standards for aggregates for use on the interstate system will be the same as for those used on the rest of the primary and urban systems. Also we shall be very reluctant to down-grade the standards in order to obtain a larger volume of materials. Obviously we are concerned with the structural soundness of both pavements and structures. Also we are very much concerned with the continued satisfactory appearance of all pavements and structures after they have been put into service. The use of coarse aggregates containing very small quantities of particles that disintegrate very quickly upon freezing and thawing or wetting and drying will result in pitting and scaling of surfaces of portland cement concrete and even bituminous surfaces in a very short time. Such portland cement or bituminous concrete usually is structurally sound and will serve a good many years. However it is difficult to explain to the public the unsightly appearance of such pavements. The deleterious materials which result in this condition are usually shale or chert particles, mud-balls, coal, sticks, etc., and the permissible maximum quantities of these are limited by specifications.

The following characteristics of aggregates for use in highway work are usually specified and I would like to consider each of them briefly.

1. Grading
2. Per cent of wear in Los Angeles Rattler Test
3. Soundness or durability tests

Grading

The 1955 AASHO Book for Highway Materials contains under specification M 43-49 a table for "Standard Sizes for Coarse Aggregate for Highway Construction." There are in this table 19 gradings or sizes each designed or suitable for some specific purpose. This table conforms in every detail to the table of sizes adopted in 1948 by your industry as Simplified Practice. All of the grading requirements for various types of construction specified in the 1955 edition of the AASHO Book for Highway Materials conform to the sizes given in the table of Simplified Practice. For example, the grading for crushed stone for bituminous concrete surface course is the same as size No. 7 in the Simplified Practice table. We have always encouraged state highway departments to use AASHO standards. However, due to local conditions and often by mutual agreement between the state and the producer, departures are made from the Simplified Practice gradings. Such departures usually do not affect the quality of the final product, but they may cause the producer some difficulty in stocking these special gradings of aggregates. The Simplified Practice recommendations were developed to prevent this duplication of effort by the producer.

A comparison of state specifications for coarse aggregate for use in portland cement concrete pave-

ment with the Simplified Practice gradings discloses the following:

For 7 states the gradings comply exactly
For 21 they comply except for minor details
Making a total of 28 in general compliance
In 20 states the gradings are materially different than those given in the Simplified Practice table

Study is being made of the agreement between the Simplified Practice recommendations and the gradings for coarse aggregate actually specified by state highway departments for all types of construction. To date, the study has been completed for only six states, but for these six, a total of 39 different specifications for the gradings of aggregates have been examined. Of these 39 specifications, 23 differ to some extent from the Simplified Practice recommendations. In some instances, the differences are of little significance, but in others, the difference may warrant concern. Some specifications have been found to differ from Simplified Practice for all except one of the 5 to 7 sizes mentioned. And in some respects, these changes may be so marked as to vary the grading of the aggregate greatly from the practical grading shown in the Simplified Practice recommendations.

Although the small amount of data at hand prevent definite statements, it is believed that a revision of the Simplified Practice recommendations on a regional basis might be desirable. A group of states having certain common road-building practices may desire to use gradings of aggregates markedly different from those in states adjoining the group. It is also possible that crushing characteristics of different stones may make variation in the grading requirements desirable. Consequently a study should be made of state highway requirements and Simplified Practice recommendations to determine whether changes are needed in either or both. The consideration governing the several courses of action available would be the selection of that which would insure the preparation of properly-graded aggregate in suitable quality and quantity for the highway program and at the lowest cost. Of the several courses of action, the revision of Simplified Practice recommendations on a regional basis may be the most promising.

In connection with the grading of aggregates, mention should be made of a simple method for improving the quality of coarse aggregate which may be applicable to many quarries. This merely involves crushing the aggregate to a smaller maximum size. In many quarries, thick beds of shale or chert must be worked with the better rock. If a 2 in. maximum size aggregate is used, large pieces of shale or chert may be found in the processed material. These certainly are undesirable in concrete or bituminous surfacing. However if the maximum size of the aggregate is reduced to 1 in., and particularly if the rock is crushed and recrushed, the shale or chert may be reduced in size to a greater extent than the remainder of the rock, and the general quality of the aggregate improved. It is suggested that quarry operators who must process some unsound material in otherwise sound rock, might study the beneficiation of the rock effected by recrushing to a smaller size. In some quarries, this treatment may be necessary for only a portion of the material processed.

As a final comment with respect to grading, it is suggested that each producer study the grading requirements of the state highway departments to which he furnishes material, and determine whether these requirements result in uneconomical production of aggregates. If in any area it is found that the grading requirements necessitate wasteful production practices of the majority of established plants, we shall be glad to confer with the producers and the state in an effort to resolve the differences.

Los Angeles Abrasion

The percentage of wear by the Los Angeles abrasion test as specified by various states is quite variable. A compilation of the maximum percentages specified for crushed stone for use in portland cement concrete pavement shows values varying from 30 per cent to 65 per cent at 500 revolutions. One state specifies 65 per cent, one 60 per cent and one 55 per cent. The values for the remaining states are 50 per cent or lower. The AASHO requirement is 40 per cent for this type of construction and the Bureau specification for forest and park work is 50 per cent. The maximum percentage of wear specified is often based on local conditions and a value as high as 65 per cent is usually justified by the satisfactory performance record of pavements in which it has been used. A report made in 1937 to the Highway Research Board by D. O. Woolf indicates that the use of aggregates having high losses in the Los Angeles machine usually results in lower strength concrete and in excessive breakage under rollers in bituminous construction. For bituminous surface treatments a maximum loss of 40 per cent or less is

almost imperative. Unless a performance record is available we believe a value not greater than 40 per cent for bituminous construction should be specified.

Soundness

Soundness tests of aggregates have been made for many years by highway laboratories to estimate their suitability for use in pavements and structures. The sodium or magnesium sulfate test is used in 35 states, freezing and thawing in 6, and 7 states have no requirement. The specified loss in the sodium or magnesium test ranges from 8 to 15 per cent in five cycles. Twenty-two states specify a loss of 12 per cent or less in 5 cycles, 8 specify 15 per cent or less, one has a requirement of 10 per cent in 10 cycles, one shows 15 per cent in 10 cycles, and one requires 20 per cent in 8 cycles. The requirement in the AASHO Specifications for Highway Materials and the Bureau FP-57 is 12 per cent loss in 5 cycles. These differences in requirements come about for two reasons (1) the method provides for making the test in several different ways and the loss requirement is based on the particular procedure used; and (2) the percentage loss may have been correlated with the performance record of the aggregate over many years of service. The wide use of this test may be attributed to the ease of making it and to the fact that it does not require elaborate apparatus. Generally the results of this test should not be used to reject materials but aggregates having a low loss in the test can confidently be assumed to be resistant to the effects of freezing and thawing.

The states using freezing and thawing tests have worked out their own procedures and it is safe to assume that no two are exactly alike in all of the details. The permissible losses specified have been derived by a correlation of test results with service behavior. We in the Bureau consider actual freezing and thawing to be a more reliable test than the sulfate test. However the freezing and thawing test as now specified in AASHO Method T-103 requires elaborate apparatus and is laborious to make because 50 or more cycles are usually necessary to produce results. Also the results of freezing and thawing tests must be correlated with the performance of aggregates in service. Our laboratory has made considerable progress on an investigation of the freezing and thawing of aggregates in an effort to develop a method which will be rapid and will not require costly equipment.

In the 7 states where soundness requirements are not specified coarse aggregates are available in large volume from sources with proven service records and such requirements are not necessary.

Conclusion

The aggregate characteristics that I have discussed are those used in purchase specifications. There are others of equal importance which are used by the highway engineer in evaluating materials. For example, he is interested in the reactivity of aggregate with alkalies in portland cement, in the characteristics of concrete made from given aggregates, in the stability of bituminous mixtures, and in other characteristics. But for the present, we are mainly concerned with those used in purchase specifications. Both the material producer and the highway engineer have a tremendous job to do to secure good aggregates for the highway construction program. Both have a financial interest in this work as taxpayers and should be vitally interested in seeing the greatest return for every dollar spent. If this is kept in mind, and the producer and engineer work together for mutual benefit, we shall obtain a highway system in which we can be justly proud.

New Film on Shovel Efficiency

A NEW 16 mm sound and color motion picture entitled "Power Shovel Productivity" has been produced by the Bureau of Public Roads. The film, based on extensive studies conducted by the Bureau, highlights job conditions that determine the yardage output of power shovels and demonstrates how production is affected by the speed of dipper cycle, size of dipper load, and the frequency and duration of minor delays.

Crushed stone producers will be particularly interested in the direct comparison of operating practices shown in this motion picture, and in the documented theme that a few seconds lost in each dipper cycle, recurring avoidable minor delays, and poor rock fragmentation can cut shovel output by as much as 50 per cent. These studies and the visual portrayal of their findings demonstrate that research can be of immediate and practical value.

Prints of this 30 minute film may be borrowed for showing by any responsible organization. Write to the Visual Education Department, U. S. Bureau of Public Roads, Washington 25, D. C.

Road Blocks in the Highway Program[1]

By PYKE JOHNSON
Past President
Automotive Safety Foundation
Washington, D. C.

TODAY'S panorama of highway transportation in the United States is one of a constantly changing, dynamic transition in our way of living and of making a living. The motor vehicle revolution is now in full swing. With it has come a new freedom of movement. We measure travel today, not in terms of distance as in the horse and buggy days, but in terms of time. The sole limitation is in the provision of adequate streets and roads for safe and expeditious movement of persons and goods. In this, we are still dangerously behind schedule, most importantly in our burgeoning metropolitan areas.

The latest figures from the U. S. Bureau of Public Roads show that we now have 78 million registered motor vehicle drivers who own or sit behind the steering wheels of 67 million motor vehicles. Last year these drivers drove an estimated 640 billion vehicle miles. Present estimates indicate that by 1975 they will have increased this by at least 15 per cent over the increases projected. In other words, to one trillion, two hundred billion miles!

Spot Light on Mr. Average Motorist

These astronomical figures don't begin to make sense to the average man until they are broken down in terms of his own use of the car. Then, they are seen as a reflection of what the vehicle has done to the way of living of each one of us. They are the sum of myriad short trips.

Thus, Mr. Average Motorist today drives an average of five miles to work each day. His wife shops an average distance of three miles.

All told, these estimates constitute about 65 per cent or two-thirds of the total use of the family car. The remainder is found in those homely trips which are part and parcel of the life of each of us, taking the youngsters to school, seeing a sick friend at the hospital, going to the movies, to the church, to the golf club. Once a year this is supplemented by a 300 mile vacation when the whole family packs into the family bus. Those who live in the country or in the open spaces of the West average somewhat greater mileages per trip, but the pattern of use is about the same for each of us. As the metropolitan areas extend and facilities are provided, all of these averages probably will go up. Motor trucks and buses add material distances.

The fly in the ointment today is still found in the fact that Mr. Average Motorist is only able to drive his car at 10 miles an hour at peak times in downtown traffic, at 15 miles in off peak hours, and these speeds grow constantly less. Similarly, he averages only 20 to 25 miles per hour in outlying areas. Only the provision of freeways can halve that driving time with all that that means to the growth of the total area.

Vehicles Out-Running Road Capacity

One way of dramatizing our highway deficiencies is to quote again from the Bureau of Public Roads.

As of today, assuming a uniform spacing of all motor vehicles, we have one vehicle for every 140 lane feet of streets in our urban areas and one vehicle for each 170 feet of all of the lane miles of main rural roads in the country. Yet, that's where our traffic is and you, as motorists, know out of your own experience that in peak hours that footage diminishes dangerously close to the point of absolute congestion.

Further, since World War II, the highway officials of the United States have built 104,000 lane miles of roads and streets while the motor vehicle manufacturers have built and sold for domestic use more than 233,000 miles of vehicles bumper-to-bumper. The net figure, minus the vehicles scrapped since the war, is 106,500 miles of vehicles bumper-to-bumper. No one expects them to go out of business!

Certainly the conclusion is inescapable that there is a vast job ahead in the construction and maintenance of the 3,400,000 miles of streets and roads in the United States, if we are to meet the challenge to individual "freedom of movement" which only the vehicle can now provide. We cannot safely delay the effort to catch up.

1 Presented at the 41st Annual Convention of the National Crushed Stone Association, Conrad Hilton, Chicago, Illinois, February 17-19, 1958

Modern Highway Design Saves Lives

There is another and highly significant figure to be added. As of today, the fatality curve of death on the highway is at the lowest recorded point in history—5.9 deaths per 100,000,000 miles of traffic.

As of today, we have a known mileage of about 3,100 miles of controlled access toll or free roads in the interstate and federal aid highway systems of the country. When it is remembered that these are by all odds the most heavily traveled roads in the country and that their fatality rate is about a third of that on all other types of roads and streets, it is conservative to say that at least 600 lives have been saved annually by these roads with all of the collateral reduction in serious accidents and property damage that accompanies that saving. Surely all of us should be deeply grateful for this achievement, particularly as it encompasses only a small percentage of the roads of similar character which are still to be constructed.

Federal Share of Interstate Costs Soaring

Within this framework of reference, let me turn to the situation which faces all of us as the National Highway Act completes its first nineteen months of operation.

Originally, the cost of completing the interstate system of 40,000 miles was set at $27 billion, of which the federal government was to pay $25 billion.

The highway study of 1957, made by the states and reviewed and checked by the Bureau of Public Roads, set the total at $37.6 billion, of which the federal share is roughly $34 billion. The mileage contained in these estimates is 38,548. Figuring costs at a million dollars per mile, the cost of the 1,102 miles added to the interstate system since the estimate was made brings the federal total for about 40,000 miles to around $40 billion, on the basis of present day costs.

Reasons for Costs Upswing

There are many reasons for the increase. An obvious one is the upward swing of all costs. Another is the traffic increases which lead to added lanes, extended overpasses.

More important than either is the fact that the Act requires that "local needs, to the extent practicable, suitable, and feasible, shall be given equal consideration with the needs of interstate commerce." To serve local needs as required by the above portion of the Act will require an estimated 63 per cent more highway grade separations, interchanges, other structures, and additional frontage roads than had been considered in determining the amounts authorized by the 1956 Act, says the Bureau report to Congress. Miscellaneous increases make up the balance.

Finally, the standards in the 1956 Act are absolute minimums. Going beyond them now will be true economy in many instances.

Alternatives—Program Cutback or More Funds

The situation thus presented poses one of two alternatives: either the program must be stretched out from the stated intent of Congress to do this job in ten years with three years of grace, to a total of twenty years to final completion; or further funds must be added.

A serious block to the objective is found in the language of the so-called Byrd amendment which requires that the annual apportionment of funds to the highway program must be limited to the funds available in any one year in the highway trust.

This trust was set up as a depository into which the federal government placed 56 per cent of the total excise taxes levied by the federal government against the motorist in the form of gasoline levies and taxes on cars, trucks, tires, and parts, with the express statement in the law that these funds were to be used for no other purposes.

In the Act of 1956 as passed almost unanimously by the House, there was a provision which specifically authorized the Secretary of the Treasury to make withdrawals from the general fund in those years where the highway trust fund did not meet the expenditures required each year to meet the Congressional mandate.

No provision of this character was contained in the Senate bill which was passed first.

When the measure went to the Senate and House conference, the House provision was stricken out and in its place was inserted the Byrd amendment which in practical effect made the measure from year to year, a pay-as-you-go law. The amendment was not debated on the floor of either House.

"Raids" on Highway Trust Fund?

A second disturbing factor is found in the recommendation made by Secretary of Commerce Weeks that $68 million be reassigned from the trust fund to purposes not specified in the original Act. These

"reassignments" stamped as "raids" by Senator Gore would divert one cent of the gas tax drawn from aviation to provide air-navigational aids; include forest and public land roads now charged to other accounts within the fund, and pay charges for administration costs of Treasury and Labor in connection with the modified Davis-Bacon labor provisions and operation of the trust fund by the Treasury.

On the basis of today's average costs of controlled access roads, that total denies annually the construction of 68 miles of life-saving roads.

A third retardant is the fact that the funds for the primary, secondary, and urban federal-aid roads now amounting to $875 million will be "upped" by $25 million annually for the next five fiscal years if a measure introduced by Congressman Fallon and supported by road advocates generally is passed. Since these funds have priority over interstate expenditures, the funds for this latter category will again be reduced, yet few who know the road problem will complain because of the clear need for a "balanced" system.

The interstate problem is best portrayed by the use of a series of four charts.

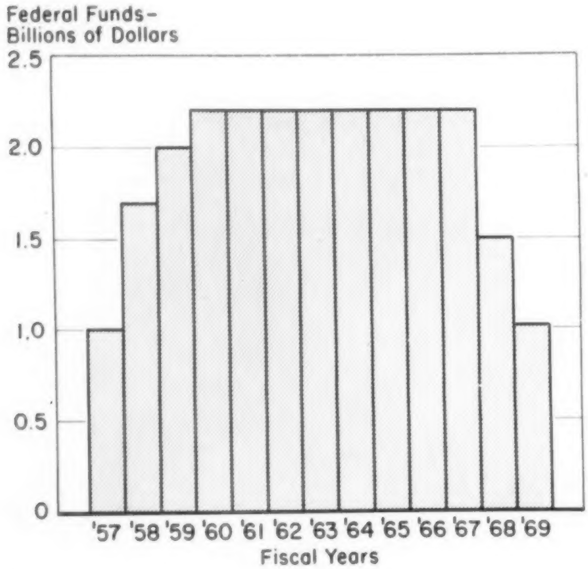


FIGURE 1
Interstate System Authorizations 1956 Act (Sec. 108(b))
($24.825 Billion)

The first chart (Figure 1) deals exclusively with the annual authorization of funds as passed by the Congress in the 1956 Act and prior to the disclosure of increases in costs.

The second chart (Figure 2) portrays graphically the impact of the Byrd amendment. Note especially that starting from taw in fiscal year 1957, this year the road forces have been able to obligate funds at a rate that keeps pace with the expansion provided initially by the Act.

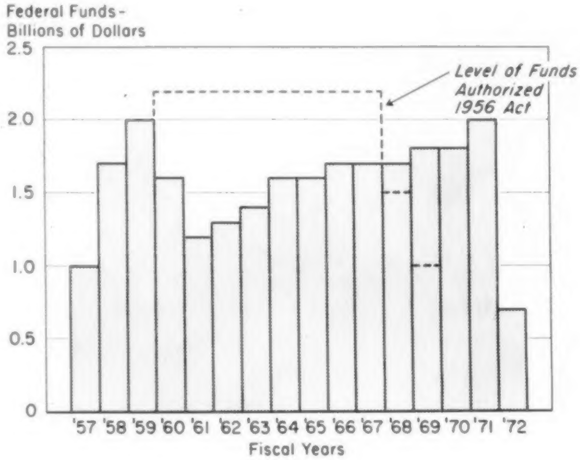


FIGURE 2
Estimated Apportionments of Interstate System Authorizations 1956 Act
(Based on Availability of Funds)
($24.825 Billion) Sec. 209(g)

The states have been able to achieve this level by a driving mobilization of all of their construction and planning forces coupled with the use of funds authorized prior to 1956. As Federal Highway Administrator Bert Tallamy has ably pointed out, the progress is not uniform in all states. Eight are ahead of time. Eight are lagging due to inadequate financial legislation or other lack of law and to inadequate planning. That side of the program is improving.

Lowered Construction Level Threatened

But having acquired that momentum, since the flow of revenue while up to expectations, is not up to the construction level of the present fiscal year of 1959, the program must be cut back from $2.0 billion in 1959 to $1.6 billion in 1960 and down to $1.2 from $2.0 billion in 1961, the year beginning July 1, 1960.

From there, estimated receipts annually while meeting the first total of estimated costs by 1972 will not permit the program to again proceed at the present year's level before 1971.

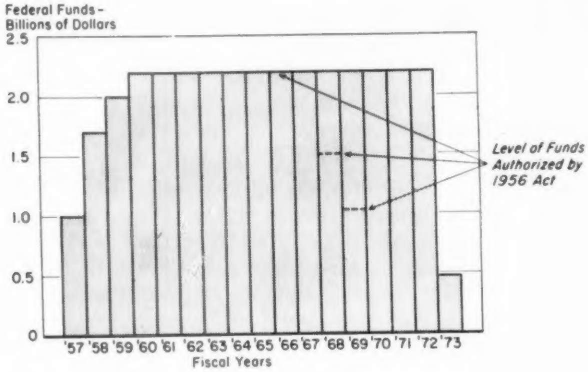


FIGURE 3
An Estimated Schedule of Interstate Apportionments Based on Section 108(d) Costs and Maximum Annual Authorization of $2.2 Billion (Same as 1956 Act) ($33.777 Billion)

As the third chart (Figure 3) shows, when to the original estimates is added the increased costs disclosed by the revised estimates if the Byrd amendment did not intervene and existing authorizations remained unchanged, the program would reach a level of $2.2 billion in the fiscal year 1960, remain there until 1972, and complete the job in 1973 or sixteen years.

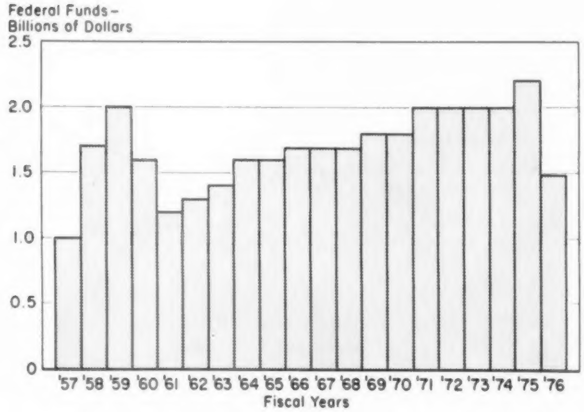


FIGURE 4
An Estimated Schedule of Interstate Apportionments Based on Availability of Funds and Section 108(d) Costs ($33.777 Billion)

If, however, as shown in the fourth chart (Figure 4) the Byrd amendment and existing authorizations are retained, then on the basis of estimated funds accruing to the trust fund from present sources, the apportionments per year would have to start at the base figure of $1.2 billion in fiscal year 1961 and from that point would not reach the sums authorized by Congress from 1960 to 1972 until 1975. Completion would come in 1976 or twenty years after the Act! Recommended reassignments would add another half year to the program.

Must Relate Program to Needs

One way in which Congress could correct this situation would be to repeal the Byrd amendment and make needed authorizations of funds for the three year period ending with the fiscal year 1962 instead of attempting to make authorizations for the total period of the program.

At that time, 1962, the second set of estimates required of the states and the Bureau by Congress will be available as will be a report on a tax system for financing the program.

By that time, Congress will have a better picture of the prevailing economy and the needs than it can have now, and collaterally it will have a better picture of conditions three or four years beyond 1962 than it could have now. Attention would be concentrated on the going rate of the program in its relation to needs rather than on totals which can never be realistically related to the going rates of expenditures which is the real test of the job to be done.

Fiscal Years 1960-62 Will Be Critical

The requirements to keep the program at the intended level for the three fiscal years from 1960 to 1962 will probably be some two or three billion dollars in excess of the program under the Byrd amendment as shown in the fifth chart (Figure 5). They can be financed by stretching out the life of the tax schedule as set up to take care of the original costs. An alternative is to draw further upon those already available motor vehicle taxes which now lie outside the trust fund and so now go into the general treasury. If bond financing is resorted to, aside from the increased costs which must be faced no matter which way the financing program grows, the added costs would be in interest charges.

Both Houses of Congress have begun hearings on the highway program but thus far the issues raised here have not been tackled. The Fallon bill is limited to a $25 million annual increase in the ABC fund for each of the fiscal years 1960 and 1961.

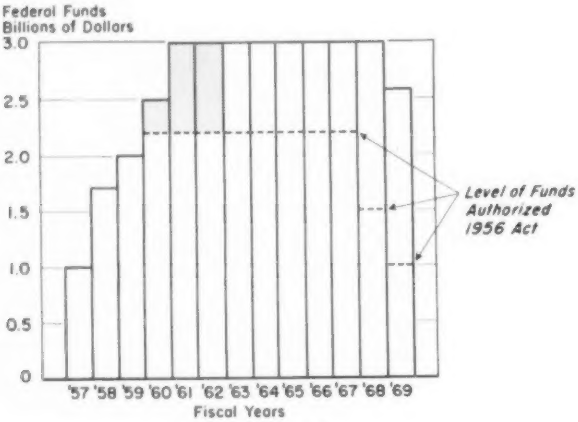


FIGURE 5

An Estimated Schedule of Interstate Apportionments Based on Section 108(d) Costs and Completion 10-13 Years

Senator Gore has asked the General Accounting Office to check the states' estimates and a corps of men are now engaged in that undertaking. Since theirs is an accounting organization, one word of caution is perhaps worth while. Experienced engineering judgment may enforce difference in costs and standards which will only appear to an auditor as evidence of wide variations in cost. Bert Tallamy has strongly defended the estimates and is prepared to support them.

Return to Original Schedule Vital

State highway officials are appearing today and tomorrow before Senator Gore's committee and they will be prepared to express full faith in their ability to carry the program forward at the rate originally planned. The question of the Byrd amendment and further financing will be subjects to be discussed by the House Ways and Means and Senate Finance Committees. Their judgment may be expected to be based on the public needs which clearly are in a return to the original schedule whether on the basis of defense, the national economy or safe and expeditious travel for the motorist who is paying the bill.

This measure is literally one of life or death. The decision finally rests with the public of which you here today are a part.

Microfilm Copies of Journal

THE Crushed Stone Journal has entered into an agreement with University Microfilms which will make available annually to libraries and other interested parties issues of the publication in microfilm form.

One of the most pressing problems facing all libraries and corporations today is providing space for the flood of publications they receive. Microfilm makes it possible to produce and distribute an entire year's contents of the Journal on a single reel, at a cost approximately equal to binding the same material in conventional form.

Sales of microfilm copies are restricted to those currently received the Journal. Copies are distributed only at the end of the volume year.

The microfilm is furnished on metal reels, in positive microfilm, suitably labelled. Inquiries concerning purchase of the Crushed Stone Journal on microfilm should be directed to University Microfilms, 313 N. First Street, Ann Arbor, Michigan.

County Engineers Named to Road Board

BERTRAM D. Tallamy, Federal Highway Administrator, has announced that nine outstanding county engineers have agreed to serve as consultants to the Bureau of Public Roads. The nine-man Board of County Engineers will provide the Bureau with a highly qualified Consultant from each geographic area of the United States. The Board will be chiefly concerned with plans involving construction and improvement of secondary or farm-to-market roads which are eligible for federal aid.

The Board of County Consultants is composed of the following nine men:

- Joe Abramson, Parish Engineer, Shreveport, La.
- W. A. Burg, Pima County Engineer, Tucson, Ariz.
- M. A. Butcher, Director of Public Works, Montgomery County, Rockville, Md.
- G. W. Deibler, County Engineer, St. Louis County, Duluth, Minn.
- Lyle Fuller, County Highway Commissioner, Marathon County, Wausaw, Wis.
- L. B. Gunderson, Chairman of the Board of County Commissioners of Salt Lake County, Salt Lake City, Utah.
- R. L. Morrison, County Engineer, Forrest and Stone Counties, Hattiesburg, Miss.
- D. B. West, County Engineer, Chelan County, Wenatchee, Wash.
- F. R. Williams, County Superintendent of Highways, Saratoga Springs, N.Y.

This Problem of Skid Resistance[1]

By A. T. GOLDBECK
Engineering Consultant
National Crushed Stone Association
Washington, D. C.

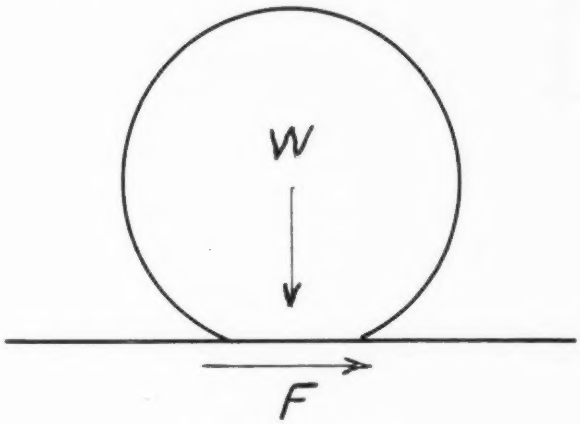
THE problem of skid resistance as applied to highways is complex. Although we are apt to think it involves only the condition of the pavement surface, actually it extends into the field of motor vehicle design, tire design, tire condition, load distribution, brakes and their operation, power plant, driver characteristics, and other matters.

It will be well to get some idea of the relative importance of skidding accidents compared with other accidents on the highways. Those who have studied the reports of skidding accidents are left with the feeling that these reports are frequently not as complete and definite as could be desired. For illustration, the skidding that takes place in an emergency may not be reported as a cause of the accident since the emergency was the primary cause. But, on the other hand, had skidding not taken place, the accident might well have been avoided. Further, recklessness or poor judgment regarding safe speed may result in a skidding accident which could have been avoided had proper driving care been exercised. So obviously, there is room for doubt as to the accuracy of reports regarding the causes of accidents.

The National Safety Council studies show that of all accidents involving skidding:

Less than 1 per cent occurred on dry pavements
18 per cent occurred on wet pavements
40 per cent occurred on snow and ice covered pavements

In Virginia an analysis[2] was made of skidding accidents per 100 million vehicle miles as compared with all accidents. Without going into details, it was found that in 1953-1954 the statewide average number of skidding accidents was 11.2 and the average of all highway accidents was 320 per hundred million vehicle miles. Thus, according to these figures, the skidding accidents were 11.2/320, or 3.5 per cent of all accidents. In the three counties having the greatest number of skidding accidents, the average number of skidding accidents was 18.2 and the average of all accidents in these same counties was 306. Thus the skidding accidents in the worst counties were 18.2/306, or 6 per cent of the total accidents. In the five counties freest from skidding, the skidding accidents per million vehicle miles were 2.4 per cent of all the accidents on the highways compared with 3.5 per cent in the most dangerous counties. These seem like small percentages compared with all the highway accidents, but they are regarded as very serious, so serious as to require corrective measures to reduce them. It is obvious, however, that corrective work, a great deal of it, will also be necessary in other phases of highway design and operation if the main causes of accidents are to be overcome. But we shall confine ourselves to our topic, that of "skid resistance."



f = coefficient of friction
W = weight on wheel
F = force of friction = fW
FIGURE 1

Let's start at the beginning and consider the influence of at least a few of the factors which influence skidding. The term skidding connotes the sliding of one surface over another, the surfaces being pressed together (Figure 1). Thus, when wheels are locked, the tires slide over the road

1 Presented at the 41st Annual Convention of the National Crushed Stone Association, Conrad Hilton, Chicago, Illinois, February 17-19, 1958
2 Reprint No. 18, University of Virginia

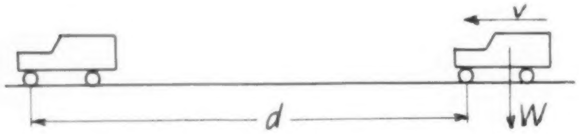
surface, either directly forward or sidewise. The tires meet with resistance to sliding and this resistance is the force of friction. For a given speed and a given condition of road surface and tire, the force of friction depends directly on the weight on the tire. Expressed mathematically, $F = fW$ where

F = force of friction between the tire and the road at any instant
W = weight on the tire
f = the so-called coefficient of friction for the surfaces involved

If the surfaces are rough, f is high; if smooth and well lubricated, f approaches zero, and hence the frictional force F approaches zero since $F = fW$. The coefficient of friction, f, equals F/W, the ratio of the force of friction to the weight or pressure between the contact surfaces. So much for the basic mechanics involved.

Slipperiness Tests on Road Surfaces

Very extensive tests have been made to determine the resistance to skidding offered by different road surfaces. These tests, thousands of them, have been conducted in different ways on many different surfaces. It will be possible to consider only typical results, mainly to indicate their significance. Those interested will find extensive literature on the subject, much of which is given in the attached list of references. It will be well to first explain just a few of the more prominent test methods made to determine the frictional resistance of the pavement.



f = coefficient of friction
v = initial velocity, ft per sec
V = initial velocity, miles per hour
d = stopping distance in ft
g = 32.2 ft per sec per sec
W = weight of vehicle in lb
then

$$\frac{Wv^2}{2g} = Fd = fWd, \text{ so } f = \frac{v^2}{2gd} = \frac{V^2}{30d}$$

$$\text{If } d = 50 \text{ ft and } V = 30 \text{ mph, } f = \frac{30 \times 30}{30 \times 50} = 0.6$$

FIGURE 2

The test most widely used at present is the stopping distance test. An automobile is run at a given speed, say 30 miles per hour, the brakes are applied to slide the wheels and simultaneously a chalk loaded pistol attached to the car is exploded to mark the road at the beginning of the test. When the vehicle stops, the distance required to bring it to rest is measured. Calculations are now made for the coefficient of friction between tire and road surface by equating the initial kinetic energy of the vehicle to the work done by the force of friction in bringing it to rest (Figure 2).

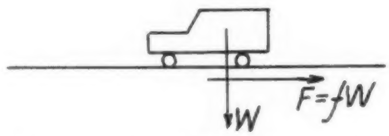
$$\frac{1}{2}\frac{W}{g}v^2 = Fd = fWd, \text{ so } f = \frac{v^2}{2gd} = \frac{V^2}{30d}$$

where f = coefficient of friction
v = initial velocity in ft per sec
V = initial velocity in miles per hr $(= \frac{60}{88} v)$
d = stopping distance in ft
g = 32.2 ft per sec per sec

Thus suppose a vehicle of weight W lb is stopped from 30 miles per hr (44 ft per sec) in a distance of 50 ft, then

$$f = \frac{44^2 \text{ (ft per sec)}}{2 \times 32.2 \times 50} = 0.6, \text{ or } f = \frac{30^2 \text{ (miles per hr)}}{30 \times 50} = 0.6$$

Actually the coefficient of friction, f, is not constant during the time the brakes are applied, but increases with decreasing speeds, hence the coefficient of friction obtained by the stopping distance method is merely an approximate measure of the variable coefficient of friction which exists during the test. However, this test method approaches the worst conditions existing during an emergency stop when the brakes are locked and the wheels are caused to slide.



a = deceleration (rate of decrease in velocity)
F = force of friction
g = 32.2 ft per sec per sec

$$F = \frac{w}{g}a = fw \text{ or } f = \frac{a}{g}$$

FIGURE 3

Still another test method consists of measuring by means of a decelerometer, the deceleration, the rate of decrease in velocity of the vehicle when the brakes are applied (Figure 3). The force which brings the vehicle to rest is the force of friction between the tires and the road surface and this force by a well known formula in mechanics is

$F = ma$ where m = the mass of the vehicle $= \frac{W}{g}$
a = the deceleration (rate of decrease of velocity) in ft per sec per sec
F, as previously explained $= fW$

$$\text{So } fW = \frac{W}{g}a$$

$$\text{or } f = \frac{a}{g}$$

The value a is the rate of decrease in velocity in ft per sec per sec and is measured by a special decelerometer mounted in the vehicle.

There are still other important methods used for determining the coefficient of friction on road surfaces and also there are certain arbitrary methods used in the laboratory which are aimed at showing the relative slipperiness of various road surfaces. In our NCSA Laboratory we have developed a method which gives a measure of the relative slipperiness of various road surfaces (Figure 4). It consists of the front wheel of a bicycle mounted in slotted supports which are readily adjustable in height. The tire is of full thickness over half its circumference and is ground down to the fabric over the remaining half. Weights are attached to the rim of the wheel. The wheel is adjusted in height so that it turns freely when the thin portion of the tire is next to the road surface but the wheel is supported on the road surface when the thick portion of the tire is in its low position. The weighted part of the wheel is brought to the top, the wheel is released and is revolved by the weight. The thick portion of the tire comes into contact with the road and friction then brings the wheel to rest. The greater the stopping angle required, the more slippery is the road surface.

FIGURE 4
Bicycle Wheel Apparatus for Measuring Slipperiness

Influence of the Characteristics of the Aggregates and of Other Variables in Road Surfaces

(a) Concrete Surfaces

When a concrete road is finished, generally an effort is made to create a non-skid surface, either by brooming with a coarse broom which creates minor corrugations in the surface or by the use of a burlap drag which likewise creates minor roughness. The fine aggregate generally projects slightly above the finished surface but, due to the abrasive action of the tires, some sands, especially those having soft particles, will wear to a flat surface and the initial projecting points thus finally present a mosaic-like appearance. The pavement surface loses its "tooth"; it no longer digs into the tire and hence the coefficient of friction is decreased. Some coarse aggregates likewise become polished and thus lose their grip on the tire.

Invariably a wet surface is more slippery than a dry surface, especially after very light moisture precipitation, for then the dust of abrasion is transformed into a thin film of oily mud which has lubricating properties. Except when ice covered, this is the most dangerous road surface condition and the most frequent skidding accidents occur at this period. Even broom marks and roughnesses produced by burlap dragging are not particularly beneficial when the aggregate is of a nature which makes it susceptible to excessive wear and polishing. It must be obvious that intensity of traffic is a major factor in influencing the period of time required for a pavement surface to become slippery. Even some hard, tough aggregates wear smooth after many years of heavy traffic.

(b) Bituminous Surfaces

Bituminous surfaces vary greatly in their characteristics due to a wide variation in the gradation of the aggregates, to the makeup of the total aggregate as between fine and coarse and particularly to the presence of an excessive quantity of asphalt. When too much asphalt is used, during the course of time the road surface becomes compressed under traffic,

the aggregate is pressed together and the asphalt is squeezed out from the voids and comes to the surface. In hot weather, asphalt expands and a pool may form on the road surface; then a really slippery condition results. There is no excuse for this defect in asphalt surfaces. It can be prevented by properly designing and producing the mix, possibly aided by the use of anti-stripping additives. Polishing of the coarse aggregates by traffic will also result in slipperiness of the bituminous pavement, but there are ways for alleviating this difficulty, such as reproportioning the mix with the use of a greater quantity of hard, fine aggregate or the application of a surface treatment, using a polish resistant cover or, perhaps of greatest benefit, is the use of a thin cover, 1/2 in. or less thick, of a special sand asphalt mix.

So much for the pavement as a factor in the skidding problem. Next let us consider some of the other contributory factors which are important.

Effect of Speed

Tests of friction have been made, very largely under the condition of locked brakes which cause the tires to slide over the road surface. That is generally the condition which exists when the driver panics and jams on the brakes.

Typical Results

Invariably tests show that the greater the speed, the less is the coefficient of friction. In Figure 5 are shown curves for the effect of speed. Note that on a selected section of new portland cement concrete, when the wheels were locked the coefficient of friction at 50 mph was 0.42, while it was 0.58 at 10 mph. Similar results were obtained with other surface types.

Impending Skid vs Locked Wheels

When the wheels were kept rolling (impending skid condition) the coefficient of friction at 50 mph was 0.67 or .67/.42 = 1.6 times that of the locked wheel condition. Surely the wheels should be kept rolling for a quick stop, and obviously the brakes and their operation are an extremely important part of this problem. Other tests have shown on wet portland cement concrete, values of f = 0.70 for impending sliding and 0.44 for the locked wheel condition, or a ratio of 0.70/0.44 = 1.58. For bleeding asphalt, wet, the values were 0.52 for impending sliding and 0.22 for the locked wheel condition, a ratio of 2.36. Thus when the wheels are kept rolling, the friction, although low, still is ample, whereas the minute the wheels are locked the coefficient of friction becomes dangerously low. On slippery road surfaces it is safer to keep the wheels rolling for then the possible retarding friction between the tire and the road can be from 60 to 136 per cent greater than when the wheels are sliding.

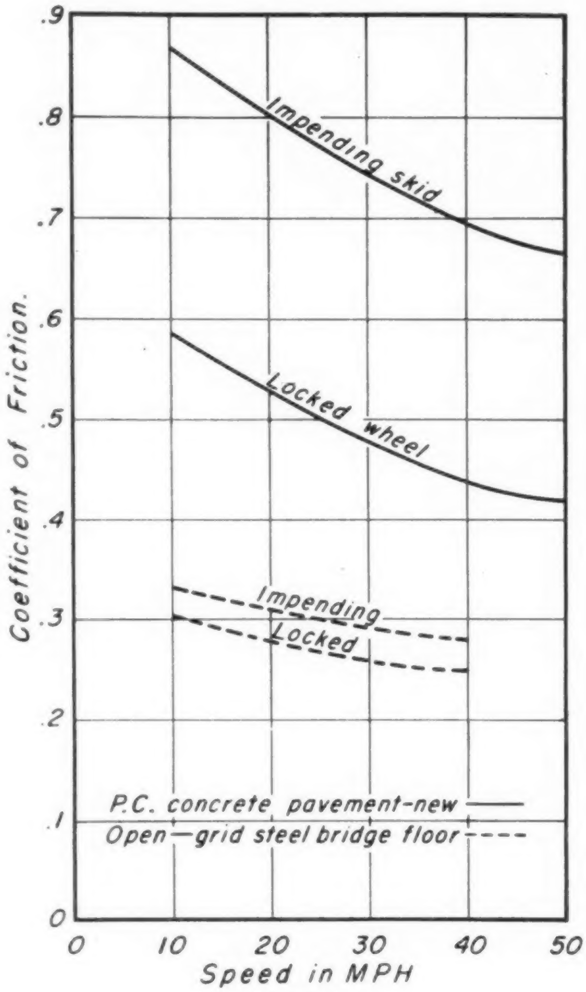


FIGURE 5
The Effect of Locked Wheel Versus Impending Skid Braking on Skid Resistance of Wet Surfaces

Stopping Distances Required—Effect of Locked Wheels

It will be interesting to compare the stopping distances resulting from the wheels rolling vs the wheels sliding methods of applying the brakes.

Assume a car traveling at 60 mph:

When the wheels are rolling (impending sliding) the coefficient of friction is, say, 0.6

When the wheels are sliding, the coefficient of friction is only, say, 0.3

Case I — wheels kept rolling, f = 0.6

We have seen that $f = \frac{V^2}{30d}$, or $d = \frac{V^2}{30f}$

where d = stopping distance, V = miles per hour initial velocity

f = coefficient of friction, so,

$$d = \frac{60 \times 60}{30 \times .6} = 200 \text{ ft}$$

Case II — wheels are caused to slide, f = 0.30

$$d = \frac{60 \times 60}{30 \times .3} = 400 \text{ ft}$$

The danger of braking so as to slide the wheels is obvious. If the wheels could be kept rolling on wet pavements during the braking operation, great benefit would result and the stopping distances would be about comparable with those on dry surfaces with present day brakes and sliding wheels.

Brakes and Their Operation

The automobile industry no doubt has attempted to improve the design of brakes. The industry is quite conscious of the desirability of brake improvement. However, the problem is exceedingly complicated for, as already pointed out, F = fW and from this formula it is seen that the force of friction on any wheel depends on the weight on that wheel. As brakes are applied, the weight on the wheel changes by a calculable amount. The evidence of this shift in weight is the dipping of the front end of an automobile under a sudden stop. Pumping of the brakes helps to keep the wheels rolling but in a panic stop the driver is apt to jam on the brakes even though he knows better. The brake designer could do a lot to help overcome the skidding problem despite variation in axle load if he could design an economical brake that would automatically keep the wheels rolling on a slippery pavement until just before the vehicle is brought to rest. No doubt this has been attempted by the automotive industry. Its successful accomplishment would prevent many accidents.

Driver Reaction Time

Driver reaction time also varies greatly (0.5 to 0.7 sec) and any change in brake design which would shorten the time between the instant of realization of danger to the instant the brakes are actually applied could mean the difference between safety and disaster. For illustration, if a car is going 60 mph, which is 88 ft per sec, and the driver's reaction time is 1/2 sec, the car will have traveled 44 ft before the driver actually applies the brakes. The automatic drive is helpful in reducing the time of brake application, for the left foot may be kept on the brake pedal ready for instant action. This, of course, requires a change in driving habit if one has been used to the standard gear shift in which the left foot operates the clutch.

Tire Design

The tire tread design undoubtedly enters into the skidding problem in a very important manner. Of late years, a number of makes of tires have been built with cuts in the tread known as "sipes" and these tires are reported to have improved resistance against sliding on wet pavements. Each "sipe" serves as a squeegee for wiping the moisture from the road surface and during sliding such "sipes" offer many inches of sharp edged resistance. Smooth treads which result when the tread becomes worn are a recognized hazard, especially on hardened pools of asphalt which are wet. The motorist for his own protection should see to it that the pattern of the tread design does not become too badly worn. Perhaps it would be an excellent idea if a limiting permissible tire condition were established and enforced by car inspection.

The Road Surface

As before pointed out, some road surfaces become slippery, primarily because they become worn by the sliding action of the tire. This sliding action may actually take place while the wheels are rolling, due in part to the application of power, to the use of brakes which may cause the wheels to slide even though they are also revolving, and finally due to the flexing of the revolving tire which causes it to rub the road surface at the area of tire contact. Naturally, some surfaces require a longer time to polish than others because their aggregates wear less readily. Any rubbing action which wears the fine and coarse aggregates so that their projecting points are worn to a flat, smooth surface causes the pavement to lose its grip and a slippery condition is created. It goes without saying that intensity of traffic controls the rate of polishing. Some surfaces made with very wear resistant aggregates have become slippery only after many years of intense traffic, while others polish more quickly. Much remains to be done on the polishing characteristics of aggregates.

Suggested Cures for Slippery Pavements

In our NCSA laboratory we have done a great deal of work on the question of slippery pavements and on methods for overcoming slipperiness. So also have some state highway departments, notably Virginia, and the indications are that the application of about 1/4 to 1/2 in. of a siliceous sand asphalt mixture spread with a standard form of paver forms a very satisfactory non-skid treatment. This mixture is much like sheet asphalt, except that it contains less asphalt and less mineral filler and possibly may contain an anti-stripping agent. Special Specifications for Plant Made Deslicking Mix as developed and used in Virginia are as follows:

GENERAL DESCRIPTION: The plant-made deslicking mix shall be composed of sand, asphalt and hydrated lime or heat stable additive, and shall be mixed at an asphalt plant conforming to Section 327 of the Virginia Department of Highways Road and Bridge Specifications dated April 1, 1954.

REQUIREMENTS:

Materials

The plant made deslicking mix shall be composed of:

(1) Sand—shall be clean and free from clay or other injurious materials, 95 per cent of the particles must be silica.
(2) Asphalt—85-100 penetration grade.
(3) Hydrated Lime or Heat Stable Additive—as specified by Materials Engineer.

Proportions

Sand—the sand used must conform to the following gradation limits:

Sieve No.	*Per Cent Passing*
No. 4	100
No. 10	95-100
No. 40	40-95
No. 80	12-30
No. 200	2-8

Asphalt Content	7.0-8.5 per cent of total mixture
Hydrated Lime	3 per cent of total mixture
Heat Stable Additive	As specified by Testing Engineer

Mixing—The mixing of the aggregate, asphalt, and hydrated lime shall be continued for 75 sec after the asphalt is added, or for as much longer as may be necessary to secure a uniform mix.

Before laying this mixture a very light tack-coat is applied to the old slippery surface. In the Virginia experiments a Barber-Greene spreader was used to apply and compact the sand asphalt mixture to a thickness of about 3/8 to 1/2 in. Rolling did not seem to further compact this surface. This treatment seems to be very effective and apparently is quite durable.

Perhaps other ways of deslicking a slippery road surface may be used, such for instance as an asphaltic emulsion grit mixture, spread and squeegeed over the old surface, or a standard surface treatment with a hard cover aggregate is effective.

Some concrete surfaces have become slippery after years of service. It will be recalled that for many years emphasis has been placed on the use of pavement mixtures which would produce as thin a mortar layer on the surface as practicable, for it was felt that thus excessive surface scaling would be prevented. It seems to be the case, however, that wherever, a siliceous sand mortar coat has remained on the surface, this mortar has not polished under traffic The question therefore may well be asked as to whether pavement concrete should not now be proportioned so as to purposely produce a thicker surface mortar layer than is now prevalent. Now that air entrainment is generally practiced, the chances are that this layer would stay in place. This is merely a thought; it may be worth investigating. Likewise, a mortar wearing surface could be used. This would require two course construction but this is not unusual and is standard practice when placing reinforcing steel.

Diverse Involvement in Slipperiness Problem

The problem of pavement slipperiness concerns not only suppliers of materials for pavements; it concerns the automotive industry, especially the designers of brakes, the tire industry, and the trailer industry. The highway engineer and of course the road user are also involved. By mutual cooperation, this problem will be overcome if everyone concerned will do his part. It will be interesting for you to know that, for the purpose of attacking the problem of skidding accidents, a move has been started by the Virginia Council of Highway Investigation and Research to hold an International Skid Prevention Conference at the University of Virginia in September 1958. Such a conference should prove to be highly beneficial, for on the program there will be discussions of all the various contributing causes of highway skidding accidents. Any cooperative move to cure the skidding problem should be welcomed by everyone concerned with highway use, for this is a move to eliminate one of the recognized causes of highway accidents. The automotive industry should reap benefit from a reduction in skidding accidents, for this will help to renew confidence in the motoring public. It will create a greater sense of safety on the highways.

Conclusion

In conclusion, I hope I have made it plain that not only do materials producers and highway engineers have a responsibility in the solution of this skidding problem, but an equally responsible part rests with the automotive industry, the tire industry, the legislative and law enforcement authorities, and with those who deal with human behavior. A tremendous road building program is in progress and no doubt every effort will be made to engineer safety into these new highways. However, these will be roads which will make attractive the use of high speeds and, as has been shown, high speeds are dangerous because, for the several reasons already discussed, there is greater potential for more serious results. It is clear that brakes and tires must be designed for greater safety against skidding; the safety features of motor vehicles need more emphasis. It is time for a sober sense of responsibility to prevail on the part of the driver and of all others concerned to the end that increased safety rather than increased power and speed will be recognized as those features most to be desired. The highway engineer too could do his part. He recognizes the skidding problem. If he made full use of facts already established he could improve the anti-skid properties of road surfaces where needed, such as at steep grades, at intersections, curves, and traffic signals. The driver needs more education and constant emphasis on correct driving habits will surely help. Proven dangerous drivers should be ruled off the road. Finally, law enforcement agencies must find ways to make the public realize the seriousness of violating traffic laws.

It is to be hoped that the approaching Skid Prevention Conference at the University of Virginia this coming September will stimulate thought on the many ways available for preventing skidding accidents. Some highway surfaces need deslicking, but that alone will not prevent skidding accidents for, as I have tried to show, many other contributing conditions exist in the vehicle and its operation which if corrected would help materially to make our highways safer.

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   13th, 1933 — 20th, 1940
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Tractors (Crawlers) and Equipment; Off-Highway Trucks; Power Units—Carbureted and Diesel

Iowa Manufacturing Co.
916 16th St., N. E., Cedar Rapids, Iowa
Rock and Gravel Crushing, Screening, Conveying and Washing Plants, Asphalt Plants, Stabilizer Plants, Impact Breakers, Screens, Elevators, Conveyors, Portable and Stationary Equipment, Hammermills, Bins

Manufacturers Division – National Crushed Stone Association
(continued)

Jaeger Machine Co.
550 West Spring St., Columbus 16, Ohio
Portable and Stationary Air Compressors, Self-Priming Pumps, Truck Mixers, Concrete Mixers, Road Paving Machinery, Hoists and Towers; Finishers—Concrete, Spreaders—Stone and Concrete

Jeffrey Manufacturing Co.
815 North Fourth St., Columbus 16, Ohio
Elevator Buckets; Car Pullers; Chains; Conveyors: Belt, Drag, Apron, Vibrating; Idlers; Crushers; Pulverizers; Elevators; Feeders; Pillow Blocks; Grizzlies; Screens

Johnson-March Corp.
1724 Chestnut St., Philadelphia 3, Pa.
Dust Control Engineers, Chem-Jet Dust Control Systems, Gas Scrubbers

Joy Manufacturing Co.
333 Henry W. Oliver Bldg., Pittsburgh 22, Pa.
Drills: Blast-Hole, Wagon, Rock, and Core; Air Compressors: Portable, Stationary, and Semi-Portable; Aftercoolers; Portable Blowers; Carpullers; Hoists: Multi-Purpose and Portable; Rock Loaders; Air Motors; Trench Diggers; Belt Conveyors; "Spaders;" "String-a-Lite" (Safety-Lighting-Cable); Backfill Tampers; Drill Bits: Rock and Core; Joy Microdyne Dust Collectors; Shovel Loaders

Kennedy-Van Saun Mfg. & Eng. Corp.
2 Park Ave., New York 16, N. Y.
Crushing, Screening, Washing, Conveying, Elevating, Grinding, Complete Cement Plants, Complete Lime Plants, Complete Lightweight Aggregate Plants, Synchronous Motors, Air Activated Containers for Transportation of Pulverized Material, Cement Pumps, and Power Plant Equipment

Kensington Steel
Division of Poor & Co.
505 Kensington Ave., Chicago 28, Ill.
Oro Alloy and Manganese Steel Castings: For Shovels—Dipper Teeth, Crawler Treads, Rollers, Sprockets; For Crushers—Jaw Plates, Concaves, Mantles, Bowl Liners; For Pulverizers—Hammers, Grate Bars and Liners; For Elevators and Conveyors—Chain, Sprockets, Buckets; For Tractors—Rail Links and Grouser Plates; Drag Line Chain

Koehring Division
Koehring Co.
3026 West Concordia Ave., Milwaukee 16, Wis.
Excavating, Hauling, and Concrete Equipment

Lecco Machinery & Engineering Co.
New Airport Road, Bluefield, W. Va.
Vibrating Screens and Vibrating Conveyors

Link-Belt Co.
300 West Pershing Road, Chicago 9, Ill.
Complete Stone Preparation Plants; Conveyors, Elevators, Screens, Washing Equipment, and Power Transmission Equipment

Link-Belt Speeder Corp.
1201 Sixth St., S. W., Cedar Rapids, Iowa
Complete Line of Speed-o-Matic Power Hydraulically Controlled Cranes, Shovels; Hoes, Draglines, and Clamshells, 1/2 to 3-Yd. Capacities; Available on Crawler Base or Rubber Tire Mounting; Diesel Pile Hammers

Lippmann Engineering Works, Inc.
4603 West Mitchell St., Milwaukee 14, Wis.
Primary and Secondary Rock Crushers and Auxiliary Equipment such as Feeders, Screens, Conveyors, Etc., Portable and Stationary Crushing and Washing Plants

Ludlow-Saylor Wire Cloth Co.
634 South Newstead Ave., St. Louis 10, Mo.
Woven Wire Screens of Super-Loy, Steel, Stainless Steel, and All Other Commercial Alloys and Metals

Mack Trucks, Inc.
1355 West Front St., Plainfield, N. J.
On- and Off-Highway Trucks, Tractor-Trailers, Six-Wheelers, from 5 to 100 Ton Capacity, Both Gasoline- and Diesel-Powered

Maclean-Hunter Publishing Corp.
79 West Monroe St., Chicago 3, Ill.
Publications: Rock Products and Concrete Products

Manganese Steel Forge Co.
Richmond St. & Castor Ave.,
Philadelphia 34, Pa.
ROL-MAN 11.00 to 14.00 Per Cent Rolled Manganese Steel Woven and Perforated Screens, and Fabricated Parts for Aggregate Handling Equipment

Marion Power Shovel Co.
Division of Universal Marion Corp.
617 West Center St., Marion, Ohio
Power Shovels, Draglines, Cranes, Truck Cranes—From 1/2 to 75 Yd.

Manufacturers Division – National Crushed Stone Association
(continued)

Marsh, E. F., Engineering Co.
4324 West Clayton Ave., St. Louis 10, Mo.
Belt Conveyors

Mayhew Supply Co., Inc.
4700 Scyene Road, Dallas 17, Texas
Blast Hole Drill Rigs

McLanahan & Stone Corp.
252 Wall St., Hollidaysburg, Pa.
Complete Pit, Mine, and Quarry Equipment—Crushers, Washers, Screens, Feeders, Etc., Semi-Portable Plants

Meissner, John F., Engineers, Inc.
308 West Washington St., Chicago 6, Ill.
Engineers—Constructors—Specialists in Plant Layout, Construction-Engineering Design, Procurement, Construction Management, Quarry Surveys, Plant and Property Appraisals

Mercer Rubber Co.
136 Mercer St., Hamilton Square, N. J.
Belting—Conveyor, Elevator, and Transmission; Hose—Air, Water, Steam, Suction, Sandblast, Miscellaneous; Rubber Chute Lining

Monsanto Chemical Co.
Inorganic Division
Lindbergh and Olive Street Road,
St. Louis 24, Mo.
Prilled Ammonium Nitrate

Murphy Diesel Co.
5317 West Burnham St., Milwaukee 14, Wis.
Engines—Industrial Engine, and Power Units for Operation on Diesel and Dual Fuel Engines. Generator Sets, AC and DC from 64 Kw. to 165 Kw. Mech-Elec Unit—Combination Mechanical and Electric Power Furnished Simultaneously

New York Rubber Corp.
100 Park Ave., New York 17, N. Y.
Conveyor Belting: Stonore, Dependable, and Cameo Grades; Transmission Belting: Silver Duck Duroflex, Soft Duck Rugged, Commercial Grade Tractor

Nordberg Mfg. Co.
3073 South Chase Ave., Milwaukee 7, Wis.
Symons Cone Crushers, and Symons Gyratory and Impact Crushers; Gyradisc Crushers; Grinding Mills; Stone Plant and Cement Mill Machinery; Vibrating Screens and Grizzlies; Diesel Engines and Diesel Generator Units; Mine Hoists; Railway Track Maintenance Machinery

Northern Blower Co.
6409 Barberton Ave., Cleveland 2, Ohio
Dust Collecting Systems, Fans—Exhaust and Blower

Northwest Engineering Co.
135 South LaSalle St., Chicago 3, Ill.
Shovels, Cranes, Draglines, Pullshovels—Crawler and Truck Mounted

Olin Mathieson Chemical Corp.
Explosives Division
East Alton, Ill.
Explosives, Blasting Caps, Blasting Accessories

Pennsylvania Crusher Division
Bath Iron Works Corp.
323 South Matlack St., West Chester, Pa.
Single Roll Crushers, Impactors, Reversible Hammermills, Ring Type Granulators, Kue-Ken Jaw Crushers, Kue-Ken Gyratories, Non-Clog and Standard One-Way Hammermills

Pettibone Mulliken Corp.
4710 West Division St., Chicago 51, Ill.
Tractor Shovels, Front End Loaders, Swing Loaders, Yard Cranes, Bucket and Fork Loaders, Motor Graders, Manganese Steel Castings, Material Handling Buckets, Clamshells, Draglines, Pull Shovel Dippers, Shovel Dippers, and Pumps

Pioneer Engineering
Division of Poor & Co.
3200 Como Ave., Minneapolis 14, Minn.
Jaw Crushers, Roll Crushers (Twin and Tripple), Impact Crushers, Vibrating and Revolving Screens, Feeders (Reciprocating, Apron, and Pioneer Oro Manganese Steel), Belt Conveyors, Idlers, Accessories and Trucks, Portable and Stationary Crushing and Screening Plants, Washing Plants, Mining Equipment, Cement and Lime Equipment, Asphalt Plants, Mixers, Dryers, and Pavers

Manufacturers Division – National Crushed Stone Association
(continued)

Pit and Quarry Publications, Inc.
431 South Dearborn St., Chicago 5, Ill.
Pit and Quarry, Pit and Quarry Handbook, Pit and Quarry Directory, Modern Concrete, Concrete Industries Yearbook, Equipment Distributor's Digest

Productive Equipment Corp.
2926 West Lake St., Chicago 12, Ill.
Vibrating Screens

Quaker Rubber
Division of H. K. Porter Co., Inc.
Tacony and Comly Sts., Philadelphia 24, Pa.
Conveyor Belts, Hose, and Packings

Reich Bros. Mfg. Co., Inc.
1439 Ash St., Terre Haute, Ind.
Rotary and "Down-the-Hole" Drilling Machines

Rogers Iron Works Co.
11th & Pearl Sts., Joplin, Mo.
Jaw Crushers, Roll Crushers, Hammermills, Vibrating Screens, Revolving Screens and Scrubbers, Apron Feeders, Reciprocating Feeders, Roll Grizzlys, Conveyors, Elevators, Portable and Stationary Crushing and Screening Plants, Mine Hoists, Drill Jumbos, Underground Loaders, and Iron Castings

Schramm, Inc.
West Chester, Pa.
Air Compressors, Rotary Drills, Pneumatic Drills, Etc.

Screen Equipment Co., Inc.
40 Anderson Road, Buffalo 25, N. Y.
Seco Vibrating Screens; Scales—Industrial, Aggregates, Truck

Simplicity Engineering Co.
Durand, Mich.
Simplicity Gyrating Screens, Horizontal Screens, Simpli-Flo Screens, Tray Type Screens, Heavy Duty Scalpers, D'Watering Wheels, D'Centegrators, Vibrating Feeders, Vibrating Pan Conveyors, Car Shake-Outs, Woven Wire Screen Cloth, Grizzly Feeders

SKF Industries, Inc.
Front St. and Erie Ave.,
P. O. Box 6731, Philadelphia 32, Pa.
Anti-Friction Bearings—Self-Aligning Ball, Single Row Deep Groove Ball, Angular Contact Ball, Double Row Deep Groove Ball, Spherical Roller, Cylindrical Roller, Ball Thrust, Spherical Roller Thrust; Tapered Roller Bearings; Pillow Block and Flanged Housings—Ball and Roller

Smith Engineering Works
532 East Capitol Drive, Milwaukee 12, Wis.
Gyratory, Gyrasphere, Jaw and Roll Crushers, Vibrating and Rotary Screens, Gravel Washing and Sand Settling Equipment, Elevators and Conveyors, Feeders, Bin Gates, and Portable Crushing and Screening Plants

Soiltest, Inc.
4711 West North Ave., Chicago 39, Ill.
Laboratory and Field Testing Apparatus: Drilling and Coring Rigs, Sieve Shakers, Sieves, Scales, Balances, Calibration Equipment, Abrasion Testing Machines, Ovens and Furnaces

Sprengnether, W. F., Instrument Co., Inc.
4567 Swan Ave., St. Louis 10, Mo.
Portable Blast and Vibration Seismograph, and Scientific Instruments

Stardrill-Keystone Co.
920 East 17th St., Beaver Falls, Pa.
Drilling Machines: Rotary Air Drills, Churn Drills, Rotary Tools, Rotary Bits, Down-the-Hole Guns, Insert Type Bits, and Water Well Drills

Stedman Foundry & Machine Co., Inc.
P. O. Box 209, Aurora, Ind.
Stedman Impact-Type Selective Reduction Crushers, 2-Stage Swing Hammer Limestone Pulverizers, Multi-Cage Limestone Pulverizers, Vibrating Screens

Stephens-Adamson Mfg. Co.
Aurora, Ill.
Belt Conveyors, Pan Conveyors, Bucket Elevators, "Amsco" Manganese Steel Pan Feeders, Vibrating Screens, Belt Conveyor Carriers, Bin Gates, Car Pullers, "Sealmaster" Ball Bearing Units, "Saco" Speed Reducers, and Complete Engineered Stone Handling Plants

Taylor-Wharton Co.
Division Harsco Corp.
High Bridge, N. J.
Manganese and Other Special Alloy Steel and Iron Castings; Dipper Teeth, Fronts and Lips; Crawler Treads; Jaw and Cheek Plates; Mantles and Concaves; Pulverizer Hammers and Liners; Asphalt Mixer Liners and Tips; Manganese Nickel Steel Welding Rod and Plate; Elevator, Conveyor, and Dredge Buckets

Thew Shovel Co.
East 28th St. and Fulton Rd., Lorain, Ohio
"Lorain" Power Shovels, Cranes, Draglines, Clamshells, Hoes, Scoop Shovels on Crawlers and Rubber-Tire Mountings: Diesel, Electric, and Gasoline, 3/8 to 2-1/2 Yd. Capacities; Thew Moto-Loader—Rubber-Tire Front End Loader 1-3/4 Yd. Capacity

Manufacturers Division – National Crushed Stone Association
(continued)

Thor Power Tool Co.
Prudential Plaza, Chicago 1, Ill.
Wagon Drills, Rock Drills, Sump Pumps, Clay Diggers, Paving Breakers, Quarry Bars, Sinker Legs, Drifters, Rock Drilling Jumbos, Raiser Legs, Push Feed Rock Drills, Air and Electric Tools, Accessories, Generator Sets, Power Trowels, Vibratory Screens

Torrington Co.
Bantam Bearings Division
3702 West Sample St., South Bend 21, Ind.
Anti-Friction Bearings; Self-Aligning Spherical, Tapered, Cylindrical, and Needle Roller; Roller Thrust; Ball Bearings

Tractomotive Corp.
County Line Road, Deerfield, Ill.
Rubber Tired Front-End Loaders (Tracto-Loaders)

Travel Drill Co.
P. O. Box 1124, Raleigh, N. C.
"Travel Drill"—Mobile Drill for Secondary Drilling in Quarries and Open Pit Work

Traylor Engineering & Mfg. Co.
Allentown, Pa.
Stone Crushing, Gravel, Lime, and Cement Machinery

Trojan Powder Co.
17 North Seventh St., Allentown, Pa.
Explosives and Blasting Supplies

Tyler, W. S., Co.
3615 Superior Ave., N. E., Cleveland 14, Ohio
Woven Wire Screens; Ty-Rock, Tyler-Niagara and Ty-Rocket (Mechanically Vibrated) Screens; Hum-mer Electric Screens; Ro-Tap Testing Sieve Shakers, Tyler Standard Screen Scale Sieves, U. S. Sieve Series

Universal Engineering Corp.
625 C Ave., N. W., Cedar Rapids, Iowa
Jaw Crushers, Roll Crushers, TwinDual Roll Crushers, Hammermills, Impact Breakers, Pulverizers, Bins, Conveyors, Feeders, Screens, Scrubbers. Bulldog Non-Clog Moving Breaker Plate and Stationary Breaker Plate Hammermills, Center Feed Hammermills. A Complete Line of Stationary and Portable Crushing, Screening, Washing, and Loading Equipment for Rock, Gravel, Sand, and Ore. Aglime Plants. Asphalt Plants

Vibration Measurement Engineers
725 Oakton St., Evanston, Ill.
Seismographic and Airblast Measurements, Seismological Engineering, Blasting Complaint Investigations, Expert Testimony in Blasting Litigation; Nation-wide Coverage; A Complete Seismograph Rental and Record Analysis Service With "Seismolog"

Werco Steel Co.
2151 East 83rd St., Chicago 17, Ill.
Castings—Manganese, Alloy Steel; Screen Plates—Perforated Steel Screen Sections and Decks; Buckets; Chains; Belt Conveyors, Idlers; Dipper—Shovel; Drop Balls; Wire Cloth; Wire Rope and Related Products; Crushers, Pulverizers

Western-Knapp Engineering Co.
50 Church St., New York 7, N. Y.
Plant Design and Construction; Operating Studies; Appraisals

White Motor Co.
842 East 79th St., Cleveland 1, Ohio
On- and Off-Highway Trucks and Tractors—Gasoline- and Diesel-Powered; Industrial Engines—Gasoline and Diesel; Power Units, Axles, Special Machine Assemblies; Crane and Shovel Carriers; Power Generating and Distributing Systems; Batteries; All Classes of Maintenance and Repair Service

White Motor Co.
Autocar Division
Exton, Pa.
Motor Trucks

Wickwire Spencer Steel Division
Colorado Fuel and Iron Corp.
575 Madison Ave., New York 22, N. Y.
Wire Cloth, Screen Sections, Screen Plate—Perforated Steel, Wire Rope—Slings

Williams Patent Crusher & Pulverizer Co.
2701-2723 North Broadway, St. Louis 6, Mo.
Hammer Mills, Crushers, Pulverizers, Roller Mills, Reversible Impactors, Vibrating Screens, Air Separators, Bins, and Feeders

Technical Publications
of the
National Crushed Stone Association

STONE BRIEFS

No. 1. How to Proportion Workable Concrete for Any Desired Compressive Strength

No. 2. How to Proportion Concrete for Pavements

No. 3. Uses for Stone Screenings

No. 4. How to Determine the Required Thickness of the Non-Rigid Type of Pavement for Highways and Airport Runways

No. 5. The Insulation Base Course Under Portland Cement Concrete Pavements

ENGINEERING BULLETINS

No. 1. The Bulking of Sand and Its Effect on Concrete

No. 2. Low Cost Improvement of Earth Roads with Crushed Stone

No. 4. "Retreading" Our Highways

No. 5. Reprint of "Comparative Tests of Crushed Stone and Gravel Concrete in New Jersey" with Discussion

No. 7. Investigations in the Proportioning of Concrete for Highways

No. 9. Tests for the Traffic Durability of Bituminous Pavements

No. 11. A Method of Proportioning Concrete for Strength, Workability, and Durability. **(Revised November 1953)**

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Single copies of the above publications are available upon request.

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